GOVERNMENT POLYTECHNIC, SONEPUR

Lecture Note On-

Hydraulic Machine and Industrial Fluied Power

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Hydraulic Turbine

Turbine

A turbine is a machine that transforms rotational energy from a fluid that is picked up by a rotor system in to usable work or energy.

Classification of Turbine

(i) According to the head and quantity of water available.

(a) Impulse Turbine (High head & Low flow)
Ex→ Pelton wheel turbine

(b) Reaction Turbine (Low head & High flow)
Ex→ frainces turbine, kaplan turbine

(ii) According to the direction of flow of water

(a) Tangential flow turbine
Ex- Pelton wheel turbine

(b) Axial flow turbine
Ex- kaplan turbine

(c) Radial flow turbine

(d) Mixed flow turbine
Ex- francis turbine

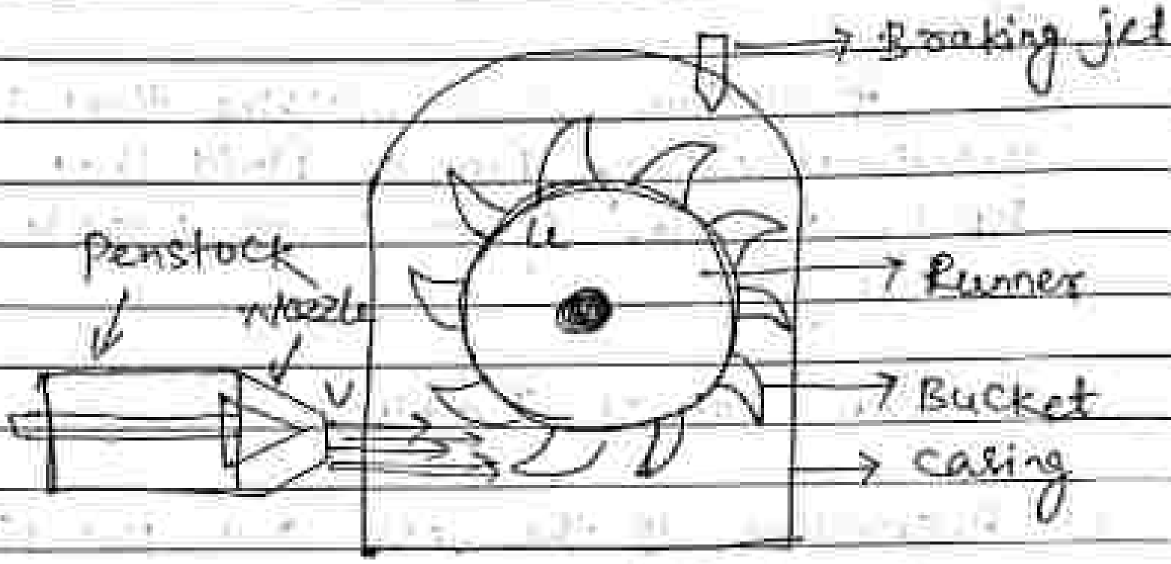
(iii) According to the name of the originator:

(a) Pelton wheel turbine (Lester Allen Pelton)
(b) Francies turbine (James Bichen Francis)
(c) Kaplan Turbine (Dr. Victor kaplan)

(iv) According to the disposition of the shaft.

(a) vertical turbine (b) Horizontal turbine

Pelton wheel Turbine



① **Nozzle and flow regulating arrangement**

→ The amount of water striking the buckets of the runner is controlled by providing a spear in the nozzle.

→ The spear is conical needle which is operated either by hand wheel or automatically in an axial direction depending upon the size of the unit

② Runner and Buckets.

→ It consists of circular disc on the periphery of which number of buckets evenly spaced are fixed.

→ The shape of buckets is of double hemispherical cup or bow.

→ Each bucket is divided into two symmetrical parts by dividing wall which is known as splitter

→ The buckets are shaped in such a way that jet gets deflected through 160° or 170°

→ Buckets is made of cast iron or stainless steel. cast iron is more economical.

→ maximum work obtained at 180° and in typical Pelton wheel there are 21 bucket.

③ Casing

→ The function of casing is to prevent the splashing of the water and to discharge water to tail race

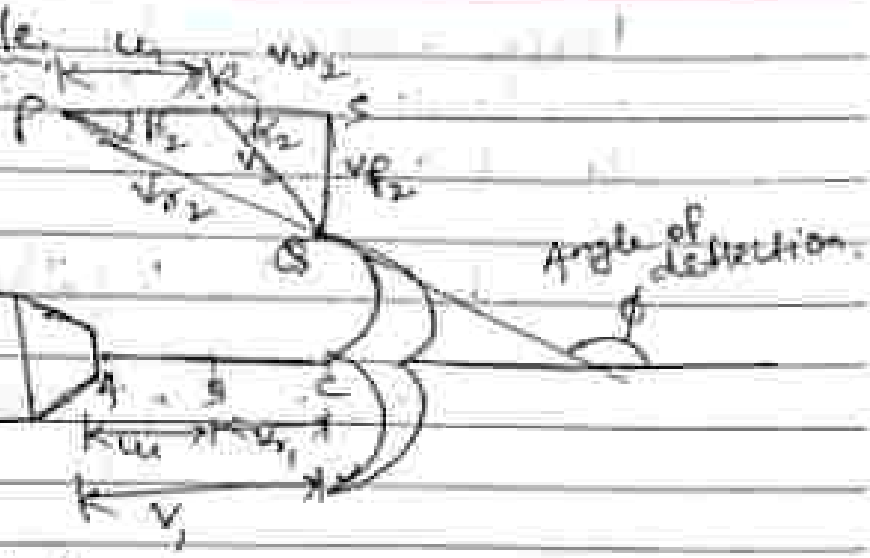
④ ~~Breaking~~ Jet

4) Breaking Jet

⇒ When the nozzle is completely closed by moving spear in the forward direction the amount of water striking the runner reduces to zero.

⇒ But runner, due to inertia goes on revolving for long time. To stop the runner in a short time, a small nozzle is provided which directs the jet of water on the back of the vanes

Velocity Triangle.



for pelton wheel turbine

① $u_1 = u_2 = u = \frac{\pi D N}{60}$

② $\alpha_1 = 0$, $\beta_1 = 0$

$V_{w_1} = V_1$ and $V_{r_1} = V_1 - u_1 = V_1 - u$

u and V_1 in same direction

for smooth surface of bucket $V_{r_1} = V_{r_2}$

for non-smooth of bucket and energy losses due to impact ~~ap~~ at splitter are considered $V_{r_2} = K V_{r_1}$ (K = blade friction co-efficient)

⇒ The pelton wheel or any other turbine is series of vanes or buckets in which whole mass of water coming from nozzle strike the buckets. Hence, mass flow rate is in term of V_1 insted of V_{r_1}

$$m = \rho A V_1$$

Force exerted by the jet of water on bucket in the direction of motion of blade :

$$F_x = \rho A V_1 [V_{w_1} \pm V_{w_2}]$$

where, A = area of crossection of jet

$= \frac{\pi}{4} d^2$

d = diameter of jet

ρ = density of water

Work done = $F_x \times u$

$= \rho A V_1 [V_{w_1} \pm V_{w_2}] \times u$

Work done/unit weight $= \frac{\rho A V_1 [V_{w_1} \pm V_{w_2}] \times u}{(\rho A V_1) \times g}$

$= \frac{1}{g} [V_{w_1} \pm V_{w_2}] \times u$

K.E of jet per sec $= \frac{1}{2} m v^2$

$= \frac{1}{2} (\rho A V_1) \times V_1^2$

$= \frac{1}{2} \rho A V_1^3$

Hydraulic efficiency = $\frac{\text{work done}}{\text{K.E}}$

η_{h} ·

$$\eta_h = \frac{\rho A V_1 [V_{w_1} \pm V_{w_2}] \times u}{\frac{1}{2} \rho A V_1^3}$$

$$\eta_h = \frac{2 [V_{w_1} \pm V_{w_2}] \times u}{V_1^2}$$

(But, $V_{w_1} = V_1$, $V_{r_1} = V_1 - u = V_{r_2}$)

Also from Outlet velocity triangle

$V_{w_2} = V_{r_2} \cos\beta_2 - u$ $\quad \left(\cos\beta_2 = \frac{u + V_{w_2}}{V_{r_2}} \right)$

$= V_{r_1} \cos\beta_2 - u$

$V_{w_2} = (V_1 - u) \cos\beta_2 - u$

$$\Rightarrow \eta_h = \frac{2 [V_1 + (V_1 - u)\cos\beta_2 - u] \times u}{V_1^2}$$

$$= \frac{2 [(V_1 - u) + (V_1 - u)\cos\beta_2] \times u}{V_1^2}$$

$$\Rightarrow \eta_h = \frac{2 (V_1 - u)(1 + \cos\beta_2) \times u}{V_1^2}$$

Francis Turbine

⇒ It is a reaction turbine.
⇒ Water at the inlet of the turbine is Pressure energy as well as kinetic energy.
⇒ Francis turbine is an inward flow reaction turbine.
⇒ Modern Francis turbine is mixed flow turbine. Where water enters the outer diameter of the runner in the radial direction and leaves the runner in the axial direction.

⇒ The main parts of Francis turbine are.
(i) Casing
(ii) Guide mechanism
(iii) Runner
(iv) Draft tube.
(v) Penst

(i) Casing
⇒ Spiral casing having maximum area at the entrance and nearly zero at the tip.

⇒ Area of spiral casing decrease uniformly along the circumference.

⇒ Water from penstock through guide vanes uniformly distributes over the runner vanes.

⇒ Hence, quantity of water flowing through the spiral casing uniformly decreases.

(II) Penstock:-

→ Penstock is a large diameter conduit which carries water from a dam or reservoir reservoir to the turbine house.

→ Francis turbine requires large amount of water than Pelton wheel.

→ Generally Penstock are made of steel.

→ Trash racks are provides at the inlet of Penstock to ensure that no debris and other foreign matter enters in to the Penstock.

(III) Guide Blades.

→ Guide blades are of airfoils shape.

→ They are fixed between two rings in form of wheel.

→ They can swing about their own axis.

→ The water quantity passing through guide blade depends on the position of guide blade.

→ Guide blades are generally made of cast iron.

(iv) Runner

→ It is the most important component of francis turbine.

→ Water with high K.E and P.E flows through the runner and makes runners to rotate and generates power.

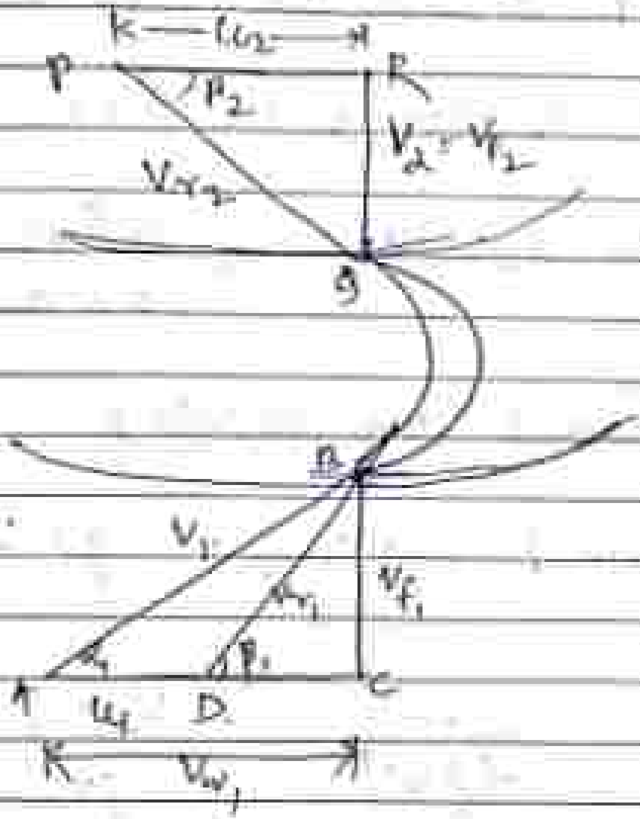
→ In francis turbine runner the flow of water is combination of radial and axial.

→ Enters radially inward and leaves in direction parallel to axis of rotor.

(v) Draft Tube

→ The draft tube is a pipe of gradually increasing area which connects the outlet to the runner to the tail race.

Velocity Triangle



V_1 = Velocity of jet at inlet

u_1 = Velocity of blade at inlet

α_1 = Angle between direction of the jet direction of motion of the blade at inlet. (guide blade angle)

V_{r_1} = Relative velocity of the jet at inlet

β_1 = Angle between the relative velocity V_{r_1} and direction of motion of the blade at inlet (blade angle at inlet)

V_{w_1} = The component of the velocity of the jet V_1 in vertical direction

V_{f_1} = The component of the velocity of the jet V_1 in the vertical direction.

Work done per second
$$= \rho A V_1 [V_{w_1} \times u_1 \pm V_{w_2} \times u_2]$$

$\{$ if $\alpha_2 > 90$, $(-ve)$
$\alpha_2 < 90$ $(+ve)$ $\}$

but here $\alpha_2 = 90$, $V_{w_2} = 0$ (Radially inward and out at radially)

so, W.D per sec $= \rho A V_1 [V_{w_1} \cdot u_1]$

W.D per sec / unit weight $= \frac{1}{g} [V_{w_1} \cdot u_1]$

Efficiency $\eta = \frac{W.D}{\rho g Q H} = \frac{\rho A V_1 [V_{w_1} \cdot u_1]}{\rho g Q H}$
$[\because AV_1 = Q]$

$$= \frac{V_{w_1} \cdot u_1}{gH}$$

~~Flow Ratio k_f~~ $=$ ~~$\frac{V_f}{\sqrt{2gH}}$~~ ~~$\frac{V_f}{u_1}$~~

Flow Ratio $(k_f) = \frac{V_f}{V_1} = \frac{V_f}{\sqrt{2gH}}$

Speed Ratio $(k_u) = \frac{u_1}{V_1} = \frac{u_1}{\sqrt{2gh}}$

Ratio of width to diameter $= \eta_1 = \frac{B_1}{D_1}$

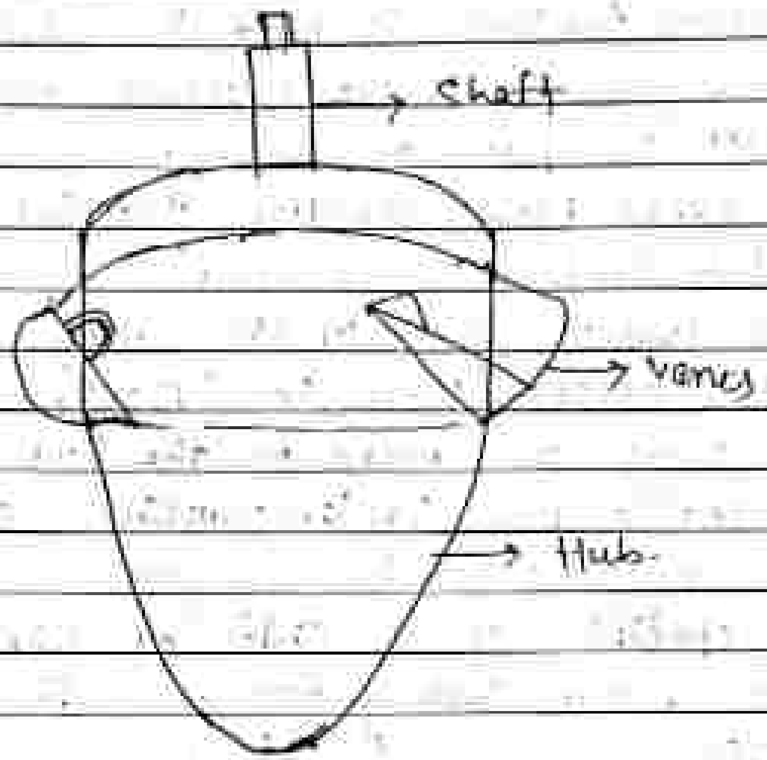
Kaplan Turbine

→ Kaplan turbine is an axial flow reaction turbine.
→ For axial flow turbines, the water flows through the runners along the direction Parallel to the axis of rotation of the runner.
→ Reaction turbine is that in which the water at the inlet of the turbine possesses K.E as well as pressure energy.
→ For axial flow reaction turbine, the shaft of the turbine is vertical.
→ The lower end of the shaft is made larger and is called "Hub" or "Boss".
→ The vane are fixed on the hub are adjusted adjustable for kaplan turbine, so that the vane angle can be changed.
→ The specific speed (Ns) of Kaplan turbine range from 300 to 600 and it is a low head turbine.

Construction and Working

Components of Kaplan turbine are similar to that of Francis turbine.
The runner vanes of Kaplan turbines are adjustable. Hence governing of kaplan turbine is carried out by governing of guide blades and runner vanes both. Kaplan turbine work with low heads, and hence the discharge through a Kaplan turbine is high.
In order to reduce contact surface of blades

with ~~at~~ water and frictional resistance, number of runner vanes of kaplan is limited 3 to 6 or 8



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* The main parts of kaplan turbine are -

(i) Scroll casing
(ii) Guide vane Mechanism.
(iii) Hub with vanes or runner of the turbine
(iv) ~~of~~ Draft tube.

(i) Scroll casing.

→ water from the Penstocks enters the scroll casing and then moves to the guide vanes

→ From the guide vanes, the water turns through 90° and flows axially through the runner.

(ii) Guide vane Mechanism

→ The Guide vanes are fixed inside the casing.

(iii) Hub with vanes

→ for kaplan turbine, the shaft of the turbine is vertical

→ The lower end of the shaft is made larger and is called Hub or Boss

→ The vanes are fixed on the hub and hence Hub acts runner for axial flow turbine.

(iv) Draft Tube:-

→ The Pressure at the exit of the runner of reaction turbine is made to be less than atmospheric Pressure by the use of draft tube.

→ water at ~~exist~~ exist is not directly discharge to the tail race.

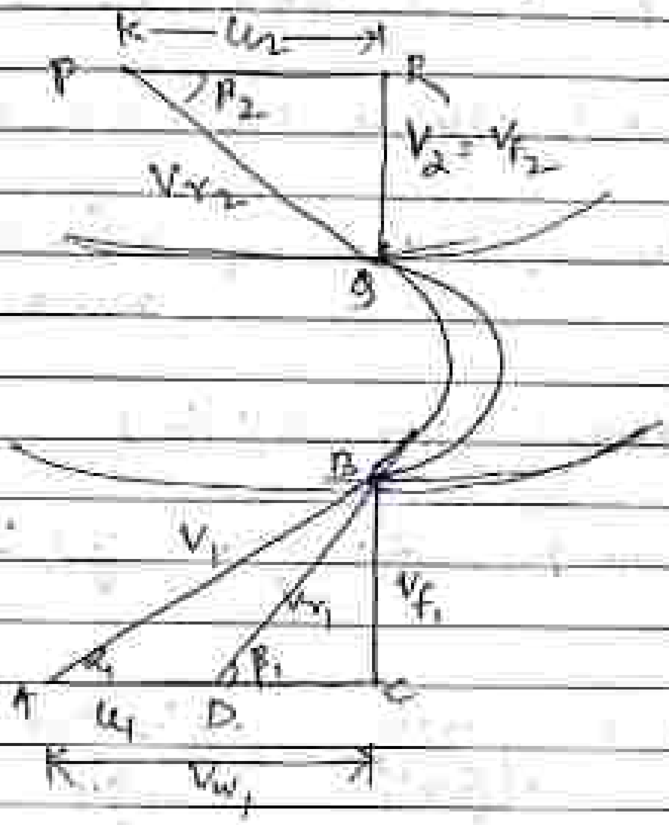
→ A tube or pipe of gradually ~~increa~~ increasing area is called draft tube.

→ The discharge through the runner is obtained as

$$Q = \frac{\pi}{4}\left(D_0^2 - D_b^2\right) \times V_{f1}$$

where, D_0 = Outer diameter of the runner
D_b = Diameter of the hub
V_{f1} = Velocity of flow at inlet

Velocity Triangle



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(−ve for $\alpha_2 > 90$ & +ve for $\alpha_2 < 90$)

but here $\alpha_2 = 90 \Rightarrow V_{w_2} = 0$ (Radially inward and out at radial)

so work done = $\rho A V_1 [V_{w_1} \cdot u_1]$

work done per unit weight = $\frac{1}{g}[V_{w_1} \cdot u_1]$

② Efficiency $\eta = \frac{W.D}{\rho g Q H} = \frac{V_{w_1} \cdot u_1}{gH}$

③ flow ratio $(k_f) = \frac{V_{f_1}}{\sqrt{2gH}}$